EFFECTS OF REAL AND IMAGINARY HAND MOVEMENTS ON EEG

O. Akgun

***Abstract*—** Our brain is one of the most complex structures in the known universe, and no matter how we want to make it simple, the way of work of it is quite complicated. In this study, the brain's structure and function that enable our movements were briefly discussed. Electroencephalography (EEG) is a non-invasive method of examination in which spontaneous electrical activity of the brain is recorded through electrodes. This examination reflects the current functional state of the brain rather than its structural properties. This study is based on an analysis of EEG signals obtained through a subject raising his left and right arm forward and then imagining him raising his left and right arm forward. First, the change of signals by the time was obtained, then the amplitude spectra of EEG signals were reached by applying the Fast Fourier Transform. Finally, the power spectrum analysis of signals was performed using the Welch method.

***Keywords*—** *Hand movements, EEG, Histogram, FFT, Welch method*

1. INTRODUCTION

ALMOST every relationship we have with the outside world involves more or less movement. Mimic movements emerging by contraction and relaxation of the facial muscles in a certain order, our conversation occurring with the work of the tongue, larynx, and mouth muscles, and making gestures with the work of the hand and arm muscles are often quite complex movements that we are not even aware of.

In medicine, the ability to move is called motor function. Even reaching out to a cup and taking it requires making a large number of calculations in our brain, creating appropriate commands by integrating different data, and then constantly fine-tuning of commands with sensory feedbacks.

The main part of the brain associated with motor function is called the primary motor cortex, or M1 area. M1 is located in the frontal lobe, along the brain curl called the precentral gyrus. Its task is to produce neural impulses that control the performing of movement. A large cortical area is required to control the complex movements of the hands and fingers, while the torso and legs, whose movements are simpler, are represented in a smaller area. In the brain, other movement-related parts are secondary motor areas. Movement signals from the brain reach the motor neurons in the part of the spinal cord called the anterior horn. The anterior horn motor neurons can receive thousands of impulses from the cortical and subcortical motor regions and intermediate neurons in the spinal cord. The impulse coming out of the front horn motor neuron goes directly to the muscle fibers and ensures them to contract [1-4]. Recording of bioelectrical activity of the brain by electroencephalography (EEG) with electrodes inserted into the scalp was first discovered by Hans Berger in 1929. For this examination, which has been also accompanied with IT technical developments over the years, amplification of very low-amplitude waves at the microvolt level and application of the filter systems are required. While all traces have been printed out to paper output, digital EEG devices are becoming increasingly common today. Digital EEG has many advantages, such as assessment of the trace more detailed and removal of artifacts [5-8]. The postsynaptic potentials that constitutes the source of the EEG are collected in the cortex, and by spreading to the scalp through the structures that surround the brain, they are recorded from the scalp with metal electrodes. The location of each electrode covered with a conductive substance is determined by standard measurements made from nasion, inion, and right and left preauricular points, and placed according to the International 10-20 system (Figure 1) [9,10]. The EEG shows potentials at various frequencies and amplitudes. Although the basic activity varies depending on age, an activity at a frequency of 8-12 Hz is observed in the parieto-occipital regions when a normal adult is awake and eyes are closed; this activity is called alpha activity. The alpha activity disappears or is suppressed when the eyes open. Beta activity is a rhythm that is evident in frontal and central regions at a frequency of 13-25 Hz. Pathological findings that may be encountered in EEG are divided into two main groups as nonspecific slow waves and epileptiform activity. The slow wave activity is grouped as theta (4-7Hz) and delta (1-3Hz) [9, 11-13].

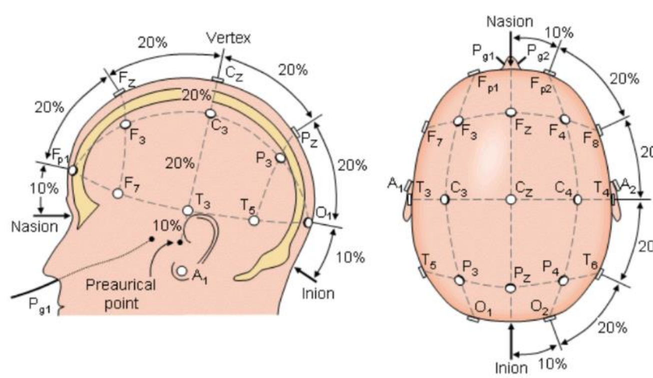

Fig.2. Map for head placement of EEG electrodes

2. APPLICATION AND MATHEMATICAL BACKROUND

The EEG signals used in this study are taken from a site called github [14]. The data was recorded from a 21-year-old right-

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handed male subject by using 19 electrodes while his eyes were closed.

In this study, the signals received from the F4 electrode (Figure 1) were used. Recording was performed first by asking the subject to raise his left hand in the air, then it was carried out by asking the subject to imagine he was raising his left hand. The same process was also repeated for his right hand.
Signal analysis was started through obtaining the change of the signal by time. Since the change of EEG signals by time is quite complex, histograms of signals were obtained and evaluated together.

By applying Fast Fourier Transform (FFT) to the signals, their amplitude spectra were taken out. Then, using Welch from nonparametric methods, power spectral density estimation of signals was made.

In order to understand this method, the Barlett method on which it is based must be expressed first. The Barlett method is defined as the method of receiving the average periodogram. In contrast to standard periodograms, in the Barlett method, the variance of the periodogram is decreased by reducing its resolution. With this method, which is widely used in physics, engineering and mathematics, the power spectrum of multiple signal windows of "n" length is taken without the overlap process. By taking the averages of the power components corresponding to the same frequency on the entire signal, inference of spectral density is performed. The Discrete-Time Fourier Transformation of each window is taken. The Welch method, on the other hand, emerged as a result of the development of the Barlett method. Here, in addition to windowing, a certain amount of overlapping process is performed on each window. This overlapping process is performed to eliminate the losses caused by the window function while moving from the center of the signal to its edges [15, 16].

The Welch method is given in the following equations.

$$x_i(n) = x(n + iD),\ n = 0,1,2,\dots,(M-1) \tag{1}$$

In Equation 1, x_i shows the data sequence, iD shows the starting point of the sequence, and M shows the generated data partitions. Equation 2 is used to calculate periodograms. Here, U is the normalization of power, and it is given in Equation 3.

$$P_x(f) = \frac{1}{MU}\left(\sum_{n=0}^{M-1} x_i(n) w(n) e^{-j2\pi f n}\right)^2 \tag{2}$$

$$U = \frac{1}{M}\sum_{n=0}^{M-1} w^2(n) \tag{3}$$

$w(n)$ is the window function. The mean of the modified periodograms gives Welch's power spectrum. The power spectrum is shown in Equation 4.

$$P_x^w = \frac{1}{L}\sum_{i=0}^{L-1} P_x(f) \tag{4}$$

where L shows the length [17, 18].

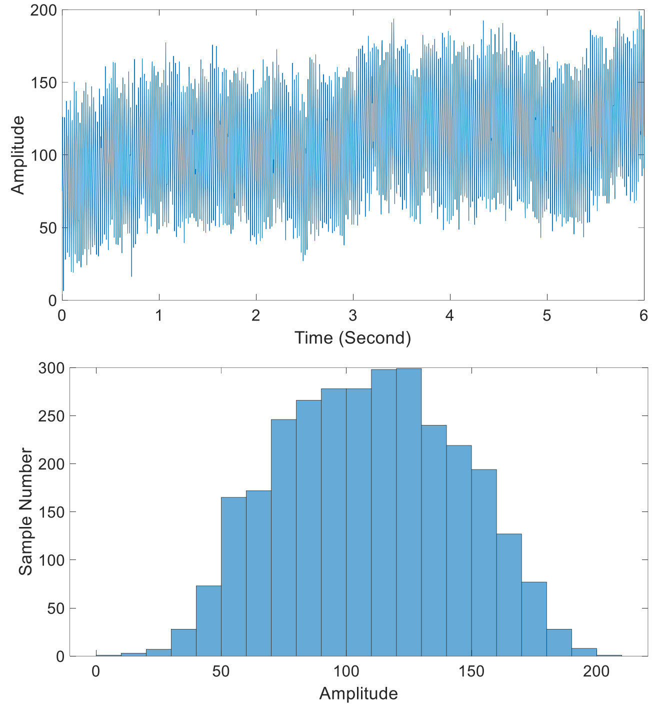

Fig.2. EEG time signal (top) and histogram (bottom) in case the left hand is raised forward.

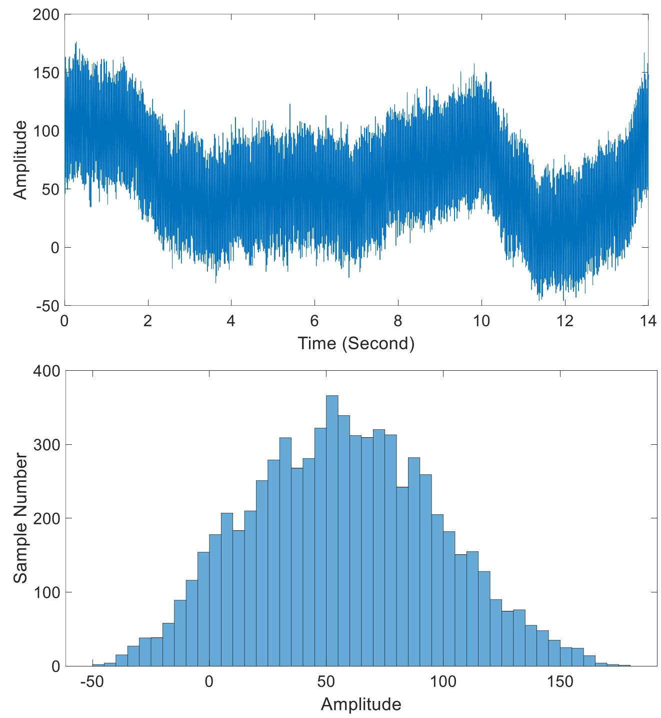

Fig.3. EEG time signal (top) and histogram (bottom) in case the left hand is imagined to be raised forward.

Although the time and histogram graphs of real and imaginary signals are similar in terms of character, the real signal receives values at positive alternant, while negative values are also observed in imaginary signal. In this sense, the positive high amplitude is more numerous in the actual signal (Figure 2, 3).

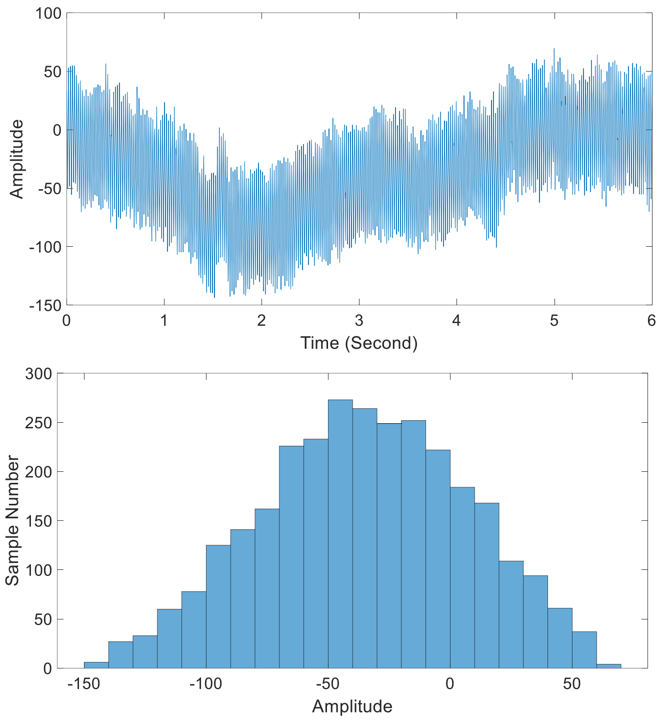

Fig.4 EEG time signal (top) and histogram (bottom) in case the right hand is raised forward.

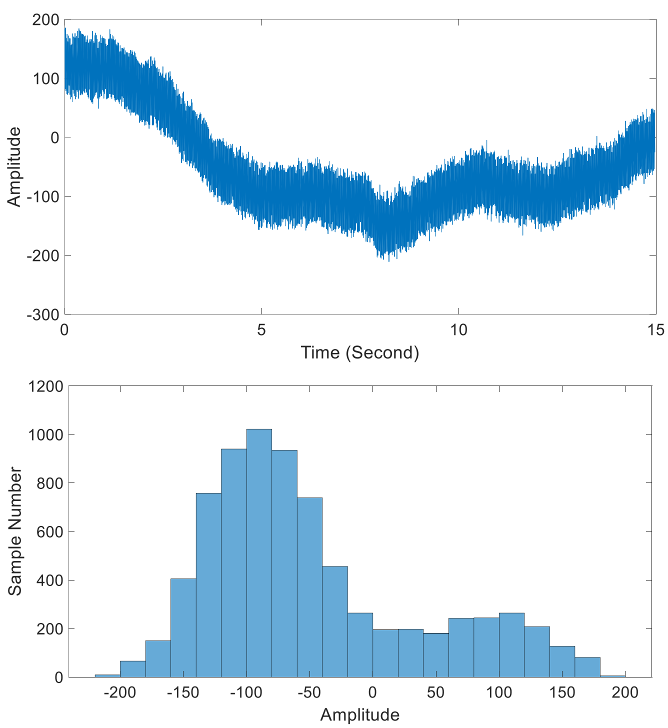

Fig.5 EEG time signal (top) and histogram (bottom) in case the right hand is imagined to be raised forward.

Considering that he is a right-handed subject, it attracts attention that there are more negative amplitudes both in reality and imagination. Especially in the imaginary right hand time change, the graph shows a decrease towards negative values (Figure 4, 5).

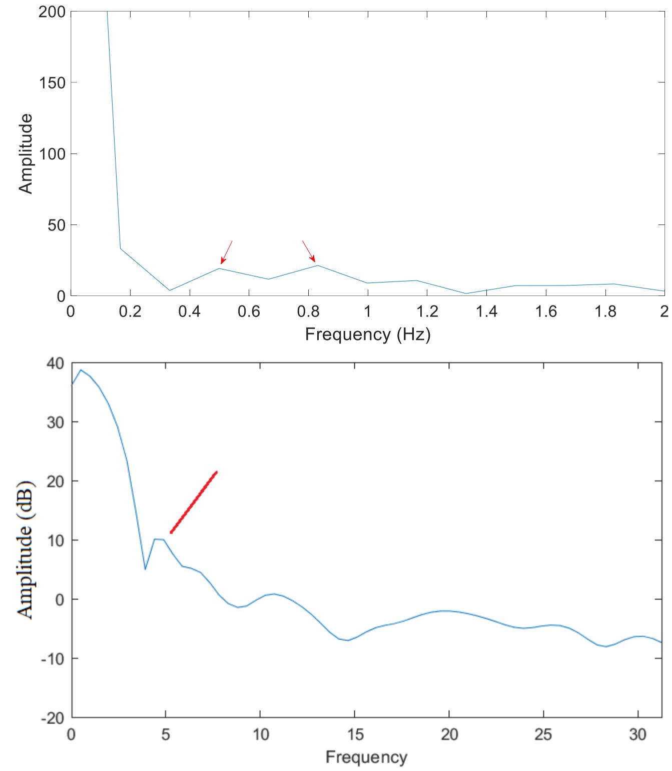

Fig.6 FFT graph (top) and power spectrum (bottom) of EGG in case the left hand is raised forward.

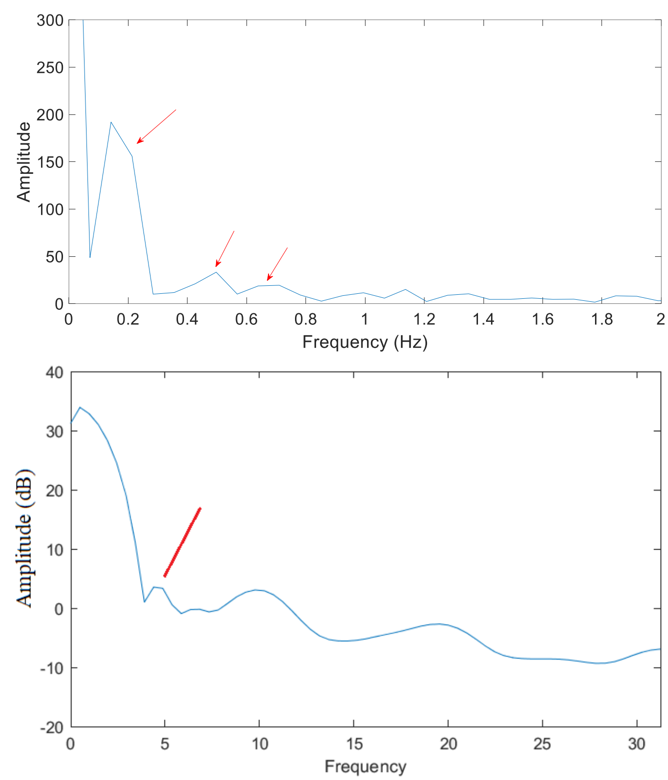

Fig.7 FFT graph (top) and power spectrum (bottom) of EGG in case the left hand is imagined to be raised forward.

In the real signal of the left hand, delta waves are attracting attention while the FFT moves towards 1Hz. In the power spectrum, the delta wave is manifesting itself with a peak of about 10 dB. Although the same waves are observed in the imaginary case, the amplitude of the delta wave in the power spectrum has decreased to 2dB.

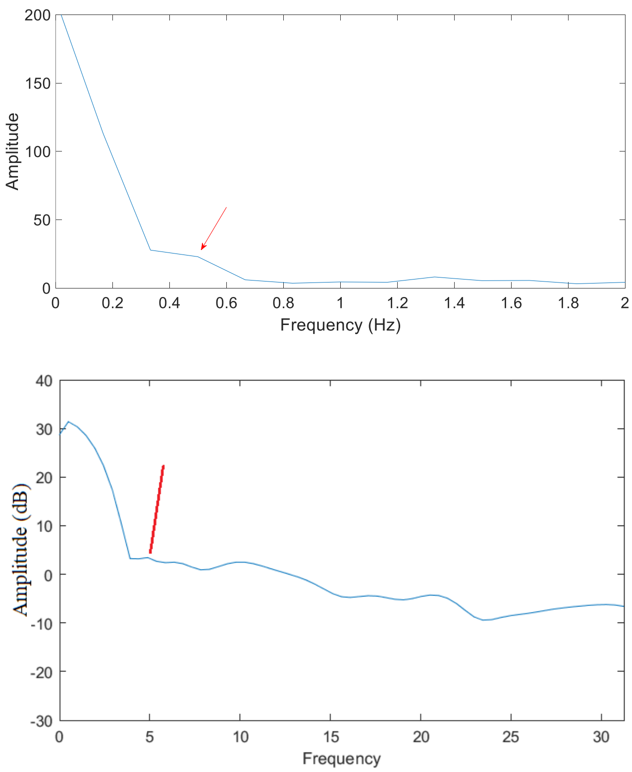

Fig.8 FFT graph (top) and power spectrum (bottom) of EGG in case the right hand is raised forward.

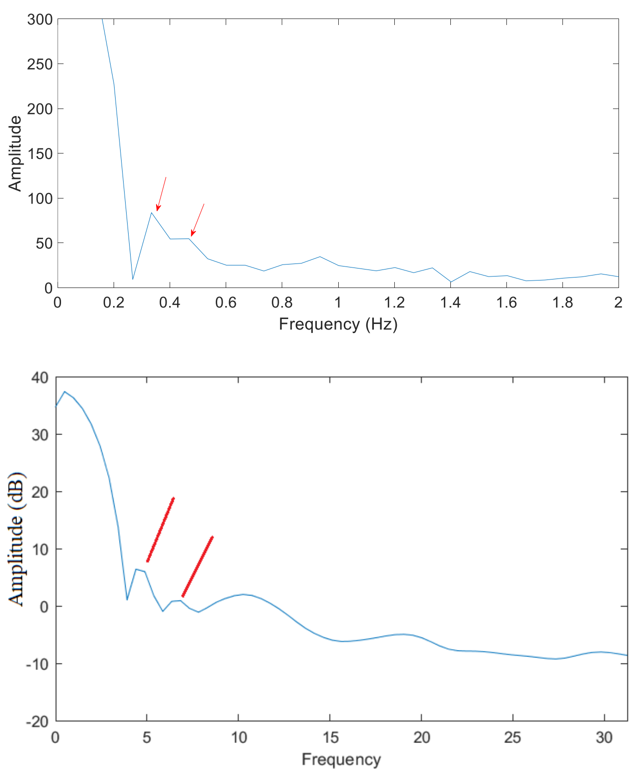

Fig.9 FFT graph (top) and power spectrum (bottom) of EGG in case the right hand is imagined to be raised forward.

The real signal of the right hand is noticed through delta waves that are at similar levels to the left hand but do not show much fluctuation. A fluctuation raising up to 75 units is observed in the FFT of the imaginary signal of the right hand. Compared to reality, there has been a rise. The same situation is seen clearly in the power spectrum.

3. Conclusions

The main part of the brain associated with motor function is called the primary motor cortex, or M1 area. This part is responsible for producing signals that ensures the performing of movement. Electroencephalography (EEG) is a non-invasive examination method in which spontaneous electrical activity of the brain is recorded through electrodes. This examination reflects the current functional state of the brain rather than its structural properties. In the EEG, the alpha wave oscillates at frequencies of 8-12 Hz, beta activity at 13-25 Hz, theta wave at 4-7 Hz, and delta wave at 1-3 Hz. Since the graph of the change of EEG by time showed a fairly intense signal density, it was more efficient to evaluate it together with the histogram. Because he was a right-handed subject, negative amplitudes were much more intense in both real and imagination signals related to the right hand compared to the left hand. In the frequency zone analysis, the primarily noticeable thing is the changes in delta activity. In the real case of the left hand, the delta wave in the power spectrum is 10 dB, while in the imaginary sign it falls to 2 dB. Because the subject was right-handed, the real signals of the right hand did not show much fluctuation though they were at a similar level. However, in the imaginary case, both a raising in the amplitude level and an increase in the fluctuation were observed. In conclusion, it can be said that we first design the movements we will make in our brain, and then perform them. This situation was revealed in this study by similar characters in the graphs between real and imaginary conditions.

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BIOGRAPHIES

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